DOCUMENT RESUME

ED 183 216 IR 008 186

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TITLE Impact of a Computer-Based Communications Network on the Working Patterns of Researchers: Design for Evaluation of Effects Related to Productivity.
PUB DATE Aug 76
NOTE 29p.: Paper presented at the Annual Meeting of the American Sociological Association (August, 1976)

EDRS PRICE MF01/PC02 Plus Postage.
DESCRIPTORS *Evaluation Methods: Information Networks: Organizational Communication: *Productivity: *Research Design: Research Reviews (Publications): *Task Performance: *Telecommunication: *Teleconferencing: Use Studies

ABSTRACT

This paper describes the design of a project to evaluate the impact of computer conferencing on the productivity-related work patterns of scientists, and to determine whether they will use the network this technology makes available to them. Literature relevant to this research problem is reviewed, drawing primarily from small group research on productivity and performance, and from research analyzing scientific research organizations. The research design and approach are described in some detail, and a bibliography is attached. (Author/JEG)

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IMPACT OF A COMPUTER-BASED COMMUNICATIONS NETWORK ON THE WORKING PATTERNS OF RESEARCHERS

Design for Evaluation of Effects Related to Productivity

Robert Johansen

Jacques Vallee

Presented at

American Sociological Association
Annual Meeting, August 1976

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Paper P-46

IR008184

ABSTRACT

This paper describes the design of a project to evaluate the impact of a new communications medium on productivity-related work patterns of scientists. Computer conferencing is being introduced into the real-world environment of several research organizations and will potentially provide access to a network of persons doing related research. Both joint research efforts and major topic teleconferences will be conducted via this medium. It could thus alter the intellectual architecture of the research environment by putting colleagues "next door," even though they are geographically distant. Whether or not computer conferencing will have any measurable effects on work patterns relating to the productivity of these researchers, or whether or not they will even use the network which is potentially available to them, is the subject of the research project described in this paper.

The first section of the paper briefly reviews the literature relevant to this research problem, drawing primarily from small group research on productivity and performance, and research analyzing scientific research organizations. The second section of the paper describes the research design and approach in some detail.

IMPACT OF A COMPUTER-BASED COMMUNICATIONS NETWORK ON THE WORKING PATTERNS OF RESEARCHERS

Design for Evaluation of Effects Related to Productivity

INTRODUCTION

Preliminary evaluation of electronic communication networks among scientists suggests that new media can improve research productivity by reducing delays in information exchange, providing precise records of interaction, coordinating remotely located participants in technical projects, and generally improving the ability to deal with large amounts of information.* Yet the problems of assessing the potential effects of new media on productivity are myriad. Traditional studies of productivity in scientific research have typically used measures of success which are closely associated with academia. Judges have been asked, for instance, to evaluate individual scientists according to their "contribution to general technical or scientific knowledge in the field" and their "overall usefulness in helping the organization carry out its responsibilities" (Pelz and Andrews, 1966). The extent to which a scientist has "increased knowledge in his field through lines of research which were useful and new" has also been examined (Andrews and Farris, 1972). Data have been collected on patents and patent applications, published papers, and books, as well as unpublished technical manuscripts, reports, and formal talks (Pelz and Andrews, 1966).

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*These effects are reported for teams of geologists using computer conferencing in Jacques Vallee and Gerald Askevold, "Geologic Applications of Network Conferencing: Current Experiments with the FORUM System," in Peter Lykos, ed., *Computer Networking and Chemistry*, Washington, DC: American Chemical Society, 1975, pp. 53-66.

Moving away from the purely academic standards, Lawler, Hall, and Oldham (1974) have defined overall performance by a composite of such factors as "net change in research and development budget during the last year" and "percentage of projects meeting time schedule."*

Unfortunately, such measures of productivity, while clearly multidimensional, are not necessarily comprehensive, and there is no unifying framework within which the findings of these various approaches can be reconciled. In the extreme, "efficiency expert" approaches which seek to quantify all aspects of scientific productivity are vulnerable to what Alfred North Whitehead calls the "Fallacy of Misplaced Concreteness."** Furthermore, any attempt to understand the impact of a new communications medium must compare performance measures for alternative organizational and communications characteristics. Such direct comparisons of comprehensive productivity measures and detailed organizational analyses are indeed rare.

As part of a program of research related to computer teleconferencing,*** we are now involved in an assessment of the effects of this medium on the productivity of scientific groups. Our approach begins from several traditions, including small group research on productivity and performance as well as direct analyses of scientific research organizations. The first part of this paper reviews the relevant literature in each of

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*Edward E. Lawler, Douglas T. Hall, and Greg R. Oldham, "Organizational Climate: Relationship to Organizational Structure, Process, and Performance," *Organizational Behavior and Human Performance*, vol. 11, no. 1, 1974, p. 146.

**Alfred North Whitehead, *Science and the Modern World*, New York: Free Press, 1925. Illustrative of this point is an editorial published in *Archives of Pathology* (vol. 93, April 1972) which suggests a formula for a research productivity index given as:

$$RPI = \frac{A}{F + S + P}$$

where A is the number of articles published by a group, F is the research funds expanded, S is the total space allocated to research, and P is the total personnel.

***For a complete description of work completed to date, see Vallee et al., *Group Communication through Computers, Volumes 1-3,* Institute for the Future, Reports R-32, R-33, and R-35, July 1974, November 1974, and October 1975.

these fields; the remaining portion describes a research design which was developed specifically for groups using computer conferencing, but which may also be applicable to other communications media in similar environments.

SMALL GROUP RESEARCH ON PRODUCTIVITY AND PERFORMANCE

A logical beginning point in a search for information relevant to the problem of communications media and productivity is the literature of small group research. Overview books on group productivity and performance are now available, and Davis (1969) and Steiner (1972) are particularly good introductions. However, these general sources quickly dispell any hope for a well-organized literature base from which to draw. As Steiner says, "Present knowledge concerning group process and productivity is uneven and poorly integrated. We know a good deal about people's reactions to specific social situations, but know much less about the mechanisms by which two or more people react to one another to produce long sequences of collective action."* The problem in deriving useful information from this literature, then, is organizing and applying the results from widely varied studies. Particularly important is the identification of variables related to productivity in groups comparable to those doing scientific research.

Small group research on productivity has typically been experimental; subjects are given assignments under varying, but controlled conditions, and their performance is then assessed. These assignments, usually in the form of a "problem" to be solved, are important to the interpretation of the results. Zagona, Willis, and MacKinnon (1966) review the various experimental problems used to date, indicating that these simulations of "real-world" situations show some variation and some replication but few points of direct comparison among sample tasks. In an attempt to examine task performance in a less artificial environment, Pye, Champness, Collins, and Connell (1973) have developed a categorization system called "Description and Classification of Meetings" (DACOM), derived from actual meetings

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*Ivan D. Steiner, *Group Processes and Productivity*, New York: Academic Press, 1972, p. 12.

occurring among civil servants in Great Britain. The relationship between the DACOM categories and those used in experiments, however, is not clear. Furthermore, the DACOM categories are sometimes difficult to transfer from one social context to another. Thus, research to date indicates that "task" is an important variable in group productivity, and some effort has been made to categorize types of tasks, but the relationships between task type and performance are clearly complicated by other variables.

Group characteristics, for example, are shown to be important in a number of research efforts, but the results are far from consistent. Lorge, Fox, Davitz, and Brenner (1958) have surveyed experiments on individual and group performance from 1920-1957. On size of group, they conclude tentatively that "greater production on 'abstract' problems can be expected from smaller groups than from larger groups, and greater production on 'concrete' problems from larger groups than from smaller ones."* Raven (1965) discusses size of group as one factor related to group performance and concludes by quoting Fink's (1963) conclusion that "under no conditions were smaller groups superior" in quality of performance and group productivity, but that speed of completion of tasks was not so clearly related to group size.** As was emphasized by Lorge et al., however, these generalizations are based upon a limited amount of research and must be treated cautiously.

Other group characteristics, such as cohesiveness and morale, also appear to be important to group productivity. Shaw (1971) states that "Group members who are attracted to the group work harder to achieve the goals of the group; one consequence of this is higher productivity by more cohesive groups."*** Moos and Speisman (1962) have also examined the

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*Irving Lorge, David Fox, Joel Davitz, and Marlin Brenner, "A Survey of Studies Contrasting the Quality of Group Performance and Individual Performance, 1920-1957," *Psychological Bulletin*, vol. 55, 1958, pp. 359-360.

**Bertram H. Raven, *Group Performance*, University of California, Los Angeles, February 1, 1965, p. 3.

***Marvin E. Shaw, *Group Dynamics, The Psychology of Small Group Behavior*, New York: McGraw-Hill, Inc., 1971, pp. 200-201.

relationship of "group compatibility" to productivity and concluded that it is indeed an important factor. While such findings might seem obvious, they are nevertheless called into question by Stogdill (1972), who concludes that cohesiveness and group productivity are only conditionally related, that intervening variables must be considered. In particular, he argues that "group drive or motivation is the variable most consistently related to productivity."*

Studies of communications networks within small groups appear to be most closely related to the research task at hand. The classic studies by Bavelas (1950) and Leavitt (1951) form the foundation for this research. Their studies involve varied structures for communication channels within groups, with a focus on the virtues of the different structures in producing high speed and quality measures. Centralized networks generally produced faster, though sometimes less "creative," results (Leavitt, 1951). Later replications with complex problems, however, showed the opposite results, with the decentralized pattern being more effective (Shaw, 1964). More recent investigations suggest that intervening variables involving decision-making processes and leadership may be more important than the structure of the communication channels (Guetzkow and Simon, 1955). Thus, the structure of communication networks has a demonstrated importance, but, like other variables, can easily be blurred by intervening factors.

Zagona et al. (1966) have perhaps gone as far as anyone in trying to draw practical conclusions from small group research related to productivity. Based on their survey, they offer the following description of an ideal group structure for creative problem solving:

> It should be nonhomogeneous in terms of member personalities and in terms of attitudes, cohesive in terms of sociometric choices, and possibly should also be capable of producing some conflict between subordinate members and a member in an authority position. The group should be open and, if the group is working under stressful conditions, the leader should be firm; but if the group is working under

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*Ralph M. Stogdill, "Group Productivity, Drive, and Cohesiveness," *Organizational Behavior and Human Performance*, vol. 8, 1972, p. 39.

pleasant and relaxed conditions, the leader should be permissive and nondirective.*

Clearly, every variable mentioned in the literature of small group research on productivity is open to debate. This summary does, however, provide clues about important characteristics to observe in searching for relationships between research productivity and the introduction of a new communications medium.

DIRECT ANALYSES OF SCIENTIFIC RESEARCH ORGANIZATIONS

Numerous studies have examined scientific research environments directly, often considering the problem of research productivity. Several major books have been written (Taylor and Barron, 1963; Pelz and Andrews, 1966; Allison, 1969; Nelson and Pollock, 1970), each of which raises general questions about the nature of scientific productivity. Also, such organizations as the National Academy of Sciences (1969) and the American Psychological Association (1966) have sponsored major studies on scientific communication.

The Pelz and Andrews effort is probably the most widely acclaimed and the most comprehensive to date. They studied 1,300 scientists and engineers in 11 research and development laboratories, with responsibilities which ranged from basic research to product development. The performance of individual scientists is assessed by various judging procedures using peers and supervisors, as well as by numbers of professional papers or patents. These multiple performance measures are then correlated with various characteristics of the research environments in an attempt to discover conditions which seem to influence research productivity.

Of particular interest for our own study are the environmental characteristics related to communication. The general finding is that "those who had relatively frequent contact with colleagues tended to perform at higher

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*Zagona, S. V. et al., "Group Effectiveness in Creative Problem Solving Tasks: An Examination of Relevant Variables," *Journal of Psychology*, vol. 62, 1966, p. 134.

levels than those with less frequent contact."* Frank Andrews further analyzes the data, concluding that the findings "tended to support the hypothesis that contact with colleagues could stimulate performance. Furthermore, they suggested that this was more likely to happen if the contacts were purposefully originated by people directly concerned--the man himself or his colleagues--than if they were unplanned or originated by some third party."** Pelz and Andrews are also unable to find evidence of scientists for whom colleague contact was not useful in some measurable way. In a follow-up study six years after the original study, Farris (1969) offers further support for the notion that communications contacts can stimulate scientific performance and vice versa.

The work of Thomas Allen (1970) and his colleagues adds depth to the analysis of scientific communication by introducing the notion of communication roles, particularly that of the "gatekeeper": "The technological gatekeeper receives information from a wide variety of sources external to his organization and acts as an information source for his colleagues in his group."*** Also, Allen's work has found that there is a direct relationship between perceived accessibility of information channels and utilization of those channels. Furthermore, those channels perceived to be highest in technical quality are not necessarily those most frequently used; apparently *cost* balances value, and accessibility is the most important determinant of choice among channels (Gerstberger and Allen, 1968). These findings suggest that social ties among researchers--both within and among organizations--are an important factor in scientific productivity.****

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*Donald C. Pelz and Frank M. Andrews, *Scientists in Organizations: Productive Climate for Research and Development*, New York: John Wiley and Sons, Inc., 1966, p. 36.

**Frank M. Andrews, "Contacts with Colleagues and Scientific Performance," *Discovery*, October 1966, p. 14.

***Thomas J. Allen, James M. Piemeier, and S. Cooney, "The International Technological Gatekeeper," *Technology Review*, vol. 73, no. 5, March 1971, p. 36.

****Research on "invisible colleges" is indirectly relevant here, since it has attempted to track the effects of professional communication among colleagues. Using such techniques as surveys (Crane, 1969) and citations (Parker, Paisley, and Garrett, 1967), these studies demonstrate both the importance of information communication ties in scientific communities and the difficulty of measuring these patterns through conventional communications media typically used (e.g., letters, hallway meetings at conventions, telephone calls).

Lawler, Hall, and Oldham (1974) have applied the notion of "organizational climate" to assess the importance of an employee's subjective impressions of his own organization. They argue that climate is a variable which is related to organizational characteristics and which has a profound influence on productivity. Observing a group of 117 directors of research laboratories in the State of Connecticut and a sample of 291 scientists at 21 of those laboratories, they have concluded that the effects of climate seem more direct than those of the more basic organizational and structural variables. McCarrey and Edwards (1973), in a study of 72 biological scientists in Canada, affirm the importance of climate variables, while pointing out that "there does not appear [to be] a magical package of climate perceptions that unequivocally bind organizational system variables to individual role performance."*

The single research effort which perhaps most closely parallels the problem at hand involves a field experiment in altering the office layout of a product engineering department in an attempt to see if the new architectural design would have a measurable effect on performance (Allen and Gerstberger, 1973). In this case, office partitions were removed to create a large common work space. When a new communications medium such as computer conferencing is introduced into a research environment, there is the potential for a similar alteration of the intellectual "architecture" as a result of new communication opportunities. Allen and Gerstberger have found strong evidence that the new office structure "worked" in the sense that it was well received and used by the test group. However, there was no measurable increase in departmental performance. Such a finding may be somewhat unsatisfying, and could well be a harbinger of problems in obtaining measurable effects on research productivity resulting from the introduction of a new communications medium, even when test groups report satisfaction with it.

While sometimes seductive, the research findings noted above are far from conclusive, and they fail to provide a firm basis for structuring our

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*Michael W. McCarrey and Shirley A. Edwards, "Organizational Climate Conditions for Effective Research Scientist Role Performance," *Organizational Behavior and Human Performance*, vol. 9, 1973, p. 455.

assessment of computer conferencing. They do, however, provide a source of work pattern variables which may be related to scientific productivity (Table 1). Such variables may also be influenced by new communications media. They thus appear to be the most viable linkage between media effects and scientific productivity. Our research design is based on this linkage.

THE RESEARCH DESIGN

Three characteristics summarize the general research design: (1) the assessment is taking place in the field, with scientists involved in actual research; (2) scientific productivity is not being assessed directly, but by identifying work patterns related to research productivity; and (3) multiple measurement approaches are being developed in order to counter the complexity of the research problem.

Since a laboratory-style control of variables is not feasible in a field experiment of this type, the most realistic approach appears to be a "patched-up" design such as the quasi-experimental frameworks suggested by Campbell and Stanley (1963). They note that such an approach to field research is not without its problems: "The result is often an inelegant accumulation of precautionary checks, which lacks the intrinsic symmetry of the 'true' experimental designs, but nonetheless approaches experimentation."* The quasi-experiment strives to control, to the degree possible, the various problems of internal and external validity. In some cases, however, the nature of the environment may demand that the field "experiment" be scaled back to simply a good field study.

Comparability of experimental groups and comparability with control groups are, of course, central concerns here. Variations in group and organizational characteristics as well as process variables could easily produce different results among the groups, and these variations may have a very ambiguous relationship to the choice of communications medium. The

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*Donald T. Campbell and Julian C. Stanley, *Experimental and Quasi-Experimental Designs for Research*, Chicago: Rand McNally & Company, 1963, p. 57.

TABLE 1. SUMMARY OF VARIABLES PREVIOUSLY ASSOCIATED WITH GROUP PRODUCTIVITY

GROUP VARIABLES	ORGANIZATIONAL VARIABLES	PROCESS VARIABLES
Typologies of scientists by professional experience (Pelz & Andrews, 1966)	Excess time pressure (Andrews & Farris, 1972)	Time used in maintaining colleague contacts (Andrews, 1966)
Availability within group of requisite abilities or skills (Darley, et al., 1952)	Support for collaborative efforts (Lawler, et al., 1974)	Informal person-to-person communication (Menzel, 1966)
Leadership which is both accepted and persistent (McCarrey & Edwards, 1973; Darley, et al., 1952)	Generality/specificity of research assignments (Lawler, et al., 1974)	Extent of group participation (Darley, et al., 1952)
Physical proximity (Gerstenfeld, 1970)	Professional autonomy (Lawler, et al., 1970, 1974)	Frequency of contact with dissimilar colleagues (Pelz, 1956)
Extent of contact with colleagues (Farris, 1969)	"Organizational Climate" test instrument (Lawler, et al., 1974; McCarrey & Edwards, 1973)	Length of work day (Andrews & Farris, 1972)
Frequency of contact with colleagues (Allen, 1972; Crane, 1970; Andrews, 1966)	Communication "bonds" and "barriers" (Morton, 1969)	Self-activation of communications channel (Andrews, 1966)
Number of people with whom contact is maintained (Andrews, 1966)	Percentage of time spent on research task (Pelz, 1970)	International communication (Allen, et al., 1971)
Acceptability of information source (Gerstberger & Allen, 1968)	Accessibility of information (Gerstberger & Allen, 1968)	Diversity of work activities (Farris, 1969)
Compatability of group members (Pelz & Andrews, 1966; Moos & Speisman, 1962)	Threat reduction (Gibb, 1951)	Types of tasks or problems (Pye, et al., 1973; Zagona, et al., 1966)
Acceptance of group goal (Darley, et al., 1952)	Constraints on group (Zagona, et al., 1966)	Communication patterns (Bavelas, 1950; Leavitt, 1951)
Group cohesiveness (Schachter, et al., 1951; Darley, et al., 1952; Zagona, et al., 1966; Shaw, 1971; Stogdill, 1972)	Flexibility of work structure (McCarrey & Edwards, 1973)	Group participation (Darley, et al., 1952)
Distance between each group (Allen, 1970)	Involvement in planning (McCarrey & Edwards, 1973)	Speed of task accomplishment (Lyle, 1961)
Similarity of people with whom contact is maintained (Pelz, 1956)	Management contact (McCarrey & Edwards, 1973)	Use of differential skills of group members (Darley, et al., 1952)
Skill in written communication (McCarrey & Edwards, 1973)		
Team heterogeneity (Smith, 1971)		
Number of colleagues in own group (Zagonna, et al., 1966; Andrews, 1966)		

process of *matching* sample and control groups according to task, group, and basic personality factors is thus a crucial part of the evaluation design.

Experimental groups should be representative of those most likely to have a need for the communication network capability offered by computer conferencing. Specifically, the groups should have a high need to communicate and should be separated by geographic (or perhaps time) barriers. Two basic types of communication seem most likely to occur via computer conferencing:

> *Type A. Project Coordination:* Type A communication would typically last from 1 to 6 months, and would involve 3 to 10 remotely located individuals. This type of communication might be joint research (A1) or intersite activities (A2).
>
> *Type B. General Conferences:* Type B conferences would be topic oriented and would last from 3 to 6 weeks; they would typically involve 10 to 30 remotely located persons.

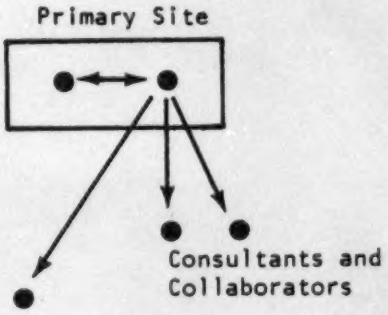
Figure 1 illustrates the likely communication structures involved in each of these types of conferences.

Among current users of computer conferences, three organizations provide candidate groups for our analysis. These are the Energy Research and Development Agency (ERDA), Electric Power Research Institute (EPRI), and National Aeronautics and Space Administration (NASA). In ERDA, there exists a Regional Studies Program which consists of coordinated regional energy studies conducted at five Atomic Energy Commission laboratories. These studies are coordinated on a national basis. A subset of this activity consists of interaction between each laboratory and its collaborators at universities and other research centers within the various regions. Within the Biomedical and Environmental Assessment Group (BEAG) at Brookhaven National Laboratory, for example, researchers are in close communication with colleagues at MIT, Harvard, and Carnegie-Mellon University. At EPRI, the Energy Systems Modeling Program is conducting analyses of fuel and energy impact on the economy, assessments of energy models, and studies of changes in energy consumption from 1947 to 1967, among others. At NASA, various groups have used, or will be using, computer conferencing for project coordination and joint research. Preliminary experimental

TYPE A1: JOINT RESEARCH

Common task (hierarchical or administrative)

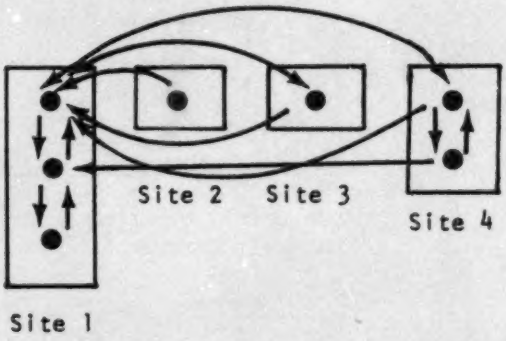
Example: An ecosystem model to include the effects of acid rain on trees and on soil pH. Researchers at Brookhaven, Livermore, and Carnegie-Mellon would be involved.



TYPE A2: INTERSITE ACTIVITIES

"Democratic"

Example: Generation and critique of a "manual" on the monitoring of health effects.



TYPE B: GENERAL CONFERENCES

Topic orientation for defined time period.

Example: A conference on effects of sulfur pollution on humans, involving researchers in the United States and Europe.

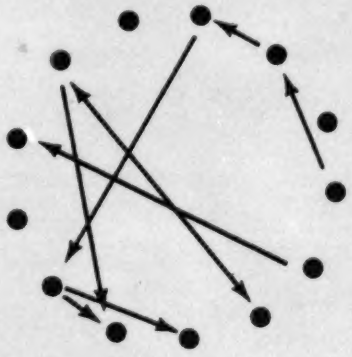


Figure 1. Types of Conferences

groups, as well as control groups using conventional media for similar communication needs, will be selected from these three organizations. This phase will be similar to a field study, where the "field" is composed of communications situations involving conventional media for group communication as well as computer conferencing. Following the preliminary study and the literature search, productivity-related factors identified in the first phase can be validated with researchers in the experimental setting.*

For this type of quasi-experimental design, Campbell and Stanley point out two possible sources of internal invalidity: maturation and selection. In the present case, the experience which users have with the medium will actually be a factor to be observed over time. Thus, initial experiences with computer conferencing may not be similar to those of highly experienced users. The variation will not only occur in technical ability, but also in styles of computer conferencing (if, in fact, variations do occur). Selection as a source of invalidity is important, although in this case, the users will *begin* with a high need to communicate. This approach does not assume that any random group of users--even within these research environments--will automatically use computer conferencing successfully; they will need to begin with a recognized need to communicate.

A practical problem arises at this point. Once a new communications medium is in use in the real world, one parameter is basic to its usage. That parameter is cost. Computer conferencing, even if it is in large-scale use, will not be free. (It will not even be inexpensive.) Any study of its impact that does not begin with a pragmatic view of cost therefore suffers from a basic flaw. In order to provide a reasonable background for the field tests outlined here, the test groups must provide financial support for the cost of communication and running the computer conferencing program. In each of the organizations identified above, the computer

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*This is one of many points at which the desire for laboratory control and the demands of a real-world environment come into tension. Hawthorne-like effects are a real possibility, but this threat is equaled by the opposite danger of using unrealistic indicators with a subject audience which is likely to be somewhat resistant.

conferencing system is being used on a commercial computer network with the test groups actually paying computer time and storage costs.*

Table 1 has already provided an initial list of work pattern variables about which information might be collected. Table 2 regroups these variables according to their relevance for the two types of sample groups identified in this research environment. The preliminary experimental groups can be used to refine this listing before final choices of work pattern variables related to productivity are made. A basically open-ended approach can be taken with these groups to identify factors (especially communication-related factors) which these researchers see as related to their own productivity.

Specifically, every accessible work pattern involving communication among sample scientists should be examined for possible effects of the use of computer conferencing. To counter the multidimensional confusion of the group communication process, a multiple measures approach must be used. The analysis is beginning with measurements of participation, frequency and length of usage of the medium, number of information sources, and similar measures and is further attempting to identify the direction and significance of any changes. The study will eventually examine correlations among the work pattern variables and, in particular, the cost data, frequency of interaction, participation data, number of person-days to complete a given task, and amount of travel for populations using either computer conferencing or conventional media.

The nature of the groups' activities and the nature of our measurements allow two types of observations here: (1) the unobtrusive gathering of information on meetings, travel, and use of media by the groups, and (2) specific interviews and questionnaires with the participants at well-defined times.

Computer conferencing provides an opportunity to conduct analyses of work patterns in a highly instrumented environment where the parameters of

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*The present costs average $20 per terminal hour, which--even though it does not include any royalty or usage charges--is probably a realistic cost figure for the near future.

TABLE 2. GROUPING OF PREVIOUSLY CITED VARIABLES RELATED TO PRODUCTIVITY BY RELEVANCE TO TELECONFERENCING GROUPS

	GROUP VARIABLES	ORGANIZATIONAL VARIABLES	PROCESS VARIABLES
RELEVANT TO TYPE "A" TELECONFERENCES ONLY	Team heterogeneity (Smith, 1971) Distance between group members (Allen, et al., 1970) Number of colleagues in own group (Zagona, et al., 1966; Andrews, 1966) Compatability of group members (Pelz & Andrews, 1966; Moos & Speisman, 1962) Availability within group of requisite ability or skill (Darley, et al., 1952) Leadership which is both accepted and persistent (McCarrey & Edwards, 1973; Darley, et al., 1952) Group cohesiveness, drive (Schacter, et al., 1951; Darley, et al., 1952; Zagona, et al., 1966; Shaw, 1971; Stogdill, 1972)	Involvement in planning (McCarrey & Edwards, 1973) Management contact (McCarrey & Edwards, 1973) Percentage of time spent on research task (Pelz, 1970)	Speed of task accomplishment (Lyle, 1961) Use of differential skills of group members (Darley, et al., 1952)
TYPE "B" ONLY		Support for collaborative efforts (Lawler, et al., 1974)	Time used in maintaining colleague contact (Andrews, 1966) Informal person-to-person communication (Menzel, 1966)
BOTH TYPE "A" AND "B"	Skill in written communication (McCarrey & Edwards, 1973) Acceptability of information source (Gerstberger & Allen, 1968) Number of people with whom contact is maintained (Andrews, 1966) Similarity of people with whom contact is maintained (Pelz, 1956) Frequency of contact with colleagues (Allen, 1970; Crane, 1969; Andrews, 1966) Extent of contact with colleagues (Farris, 1969) Typologies of scientists by experience (Pelz & Andrews, 1966) Acceptance of group goal (Darley, et al., 1952) Physical proximity (Gerstenfeld, 1970)	Accessibility of information (Gerstberger & Allen, 1968) "Organizational Climate" (Lawler, et al., 1974; McCarrey & Edwards, 1973) Excess time pressure (Andrews & Farris, 1972) Threat reduction (Gibb, 1951) Communications "bonds" and "barriers" (Morton, 1969) Constraints on group (Zagona, et al., 1966) Professional autonomy (Lawler, et al., 1970, 1974) Flexibility of work structure (McCarrey & Edwards, 1973) Generality/specificity of research assignments (Lawler, et al., 1974)	Communication patterns (Bavelas, 1950; Leavitt, 1951) Group participation (Darley, et al., 1952) Self-activation of communications channel (Andrews, 1966) Frequency of contact with dissimilar colleagues (Pelz, 1956) Length of work day (Andrews & Farris, 1972) Types of tasks or problems (Pye, et al., 1973; Zagona, et al., 1966) International communication (Allen, et al., 1971) Diversity of work activities (Farris, 1969)

interaction are easier to quantify than in most other communication environments. A monitor, which is part of the conferencing system itself, can acquire and process data on the messages exchanged in terms of timing, length, and frequency; it also gathers information related to group dynamics, user skills, and learning curves. Thus, group dynamics and individual behavior can be unobtrusively analyzed, without violating concerns for privacy of the substance of the conference.* We have also developed several analytic techniques using data gathered by the monitor. A case in point is the introduction of the "participation map" (see Figure 2). On a participation map, a member of the user group is represented by a rectangle in a space; this rectangle displays his activity as a function of the number of public and private messages** he exchanges with other group members, his "verbosity" in both modes, and his relationship to subgroups within the same conference. Participation maps can also display changes in a person's participation as he moves from conference to conference.

Critical to both the definition of productivity and the evaluation of the effects of computer conferencing is a series of interviews and questionnaires. Initial interviews (or possibly questionnaires) should elicit ratings of the task elements described above, and they should also probe more generally (1) what defines productivity for these researchers and (2) what factors are important in a productive meeting. The preconference interview schedule should include questions probing the ease of access to computer conferencing, the researchers' motivation in the tasks for which computer conferencing will be used, the nature of their work, other communications media they are likely to use, anticipated problems in the use of computer conferencing, the overall group structure, and similar concerns.

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*For more detail on the social evaluation of computer conferencing, see *Group Communication through Computers, Volumes 2 and 3*, op. cit. The general problems of social evaluation and current research on group communication through electronic media are surveyed in Johansen, Miller, and Vallee, August 1974, pp. 7-20.

**The computer conferencing program allows messages to be exchanged in three modes: public messages are seen by all participants; private messages are directed to one participant only; and anonymous messages are seen by all participants but are not identified as to author.

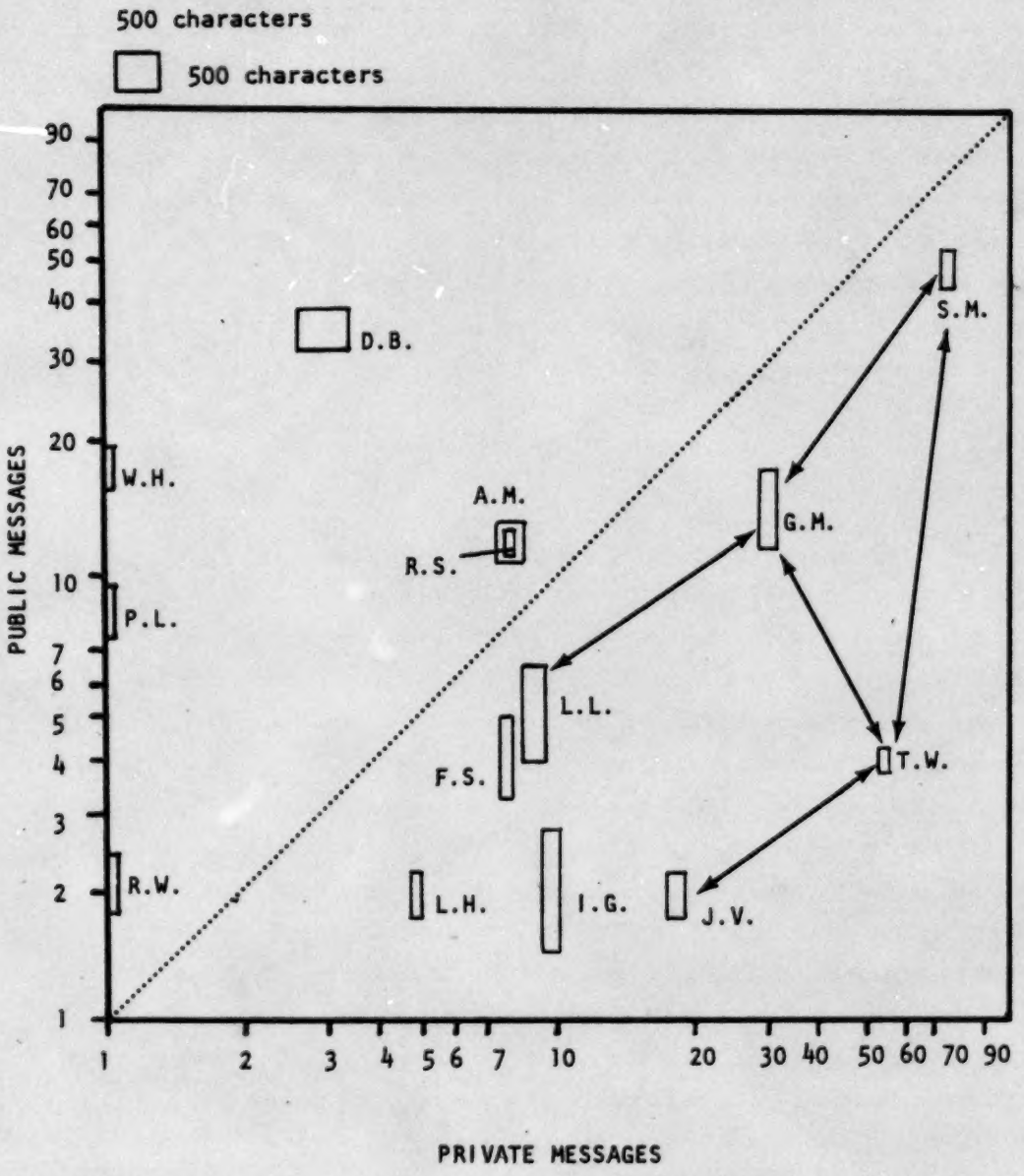

Figure 2. Participation map for a sample computer conference. Each rectangle represents an individual participant; the width of the rectangle shows the average length of private messages, while height indicates average length of public messages. Participants to the right of the diagonal sent more private messages than public; to the left, more public than private. Arrows indicate major patterns of private message exchange among participants.

Postconference questionnaires would probe the researchers' goals and the extent to which the goals were satisfied; their feelings during the conferences (e.g., frustrations, confusion, information overload); their impressions of the computer conferencing system; their motivation to participate; and other reactions related to the definition of productivity. The research approach should not, in our opinion, adopt the traditional strong separation between "evaluator" and "subject." Instead, a joint working relationship must be developed such that evaluation team has a basic understanding of the experimental environment and the "subjects" see the evaluators in a collegial rather than judgmental light.*

CONCLUSION

It would be naive to assume that one could jump from data gathering to a purely mathematical or statistical statement about the effects of computer conferencing on productivity. Translating work patterns into productivity assessments based on different communication environments will involve qualitative as well as quantitative evaluations. The classical approach to productivity has relied on the "end product" as the object to be described and measured. The present assessment, however, will focus on the *process* of research communication, regarding the outcome as only one element in this process. This approach to the evaluation of work pattern variables is thus transactional, and it is not expected to lead to a single statement or a single measure of productivity. Instead, the results would be presented as a series of statements or tables expressing the relationship of general categories of productivity-linked work pattern variables (those relating to cost, time, manpower, travel, information access and use, roles and hierarchical structures, professional attitudes, etc.) to the use of computer conferencing. These will provide the basis for a set of operational guidelines for the use of computer conferencing

*See Barnes (1967), Seashore (1964), and Campbell (1969) for varied perspectives on the operational problems of field experimentation in similar research contexts.

in similar scientific research settings, including problems in usage, reasons for nonusage, examples of successes and failures, and general reactions to the medium. The result should be an improved insight into how--if at all--computer conferencing can affect work patterns which researchers see as related to their productivity. This insight will not be absolute, but it should provide an empirical base for making intelligent choices about the relative merits and demerits of computer conferencing in this environment.

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